SINTEF

ASSESSMENT REPORT

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TITLE

Assessment of PAROC FPS 17 mineral wool boards for fire protection of steel sections:
Design Tools for Fire Protection according to ENV 13381-4:2002 and ENV 13381-4:2007 (Revision 1: 2007-04-11)

CLIENT(S)

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Paroc Building Insulation
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CLIENT REF.

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SUBJECT FOR EVALUATION

In this Revision 1 minor corrections are made with respect to rounding of the values of calculated thicknesses of PAROC FPS 17 and adaptation to available board thicknesses. Calculated thicknesses are rounded to nearest integer., and adaptation to available board thickness are made for highest rounded integer and down. (25mm covers values 20,5mm to 25,5mm).

SINTEF NBL as (NBL) is asked to assess **PAROC FPS 17 mineral wool boards** according to the calculation procedures described in ENV 13381-4 *Test method for determining the contribution to the fire resistance of structural members – Part 4: Applied protection to steel members.* Both ENV 13381-4:2002 and ENV 13381-4:2007 (draft February 2007) were used in the assessment.

Basis for the analysis are available test data from Standard Fire furnace tests of steel sections protected with **PAROC FPS 17 mineral wool boards** carried out at SINTEF NBL. The fire tests were carried out according to ENV 13381-4:2002.

MAIN CONCLUSION(S)

Design Tools for prediction of thickness of **PAROC FPS 17 mineral wool boards** on steel sections are made **for 30- 210 minutes** endurance time in a Standard Fire Exposure (R30-R210) for open and closed (I/H- and CHS/RHS-sections) steel sections.

Based on the Design Tools (graphically or tabulated values) board thickness can be chosen as a function of fire endurance time, Section Factor F/A (m^{-1}) for the section and critical steel temperature ranging from 350-700 °C.

REFERENCES:

NBL is asked to assess **PAROC FPS 17 mineral wool boards** according to the calculation procedure described in ENV 13381-4. Both ENV 13381-4:2002 and ENV 13381-4:2007 (draft February 2007) were used in the assessment.

Basis for the analysis are available test data from Standard Fire furnace tests of steel sections protected with **PAROC FPS 17 mineral wool boards** carried out at SINTEF NBL. The fire tests were carried out according to ENV 13381-4:2002.

Test Lab.	Report No.	Report Date	Test Specimens used in assessment			Application method
			Loaded beam	Short Columns	Short Beams	
SINTEF NBL	SINTEF NBL Test No. 103040.13 Test 1	2007-03-19	1	4	3	Welded pins with washers
SINTEF NBL	SINTEF NBL Test No. 103040.13 Test 2	2007-03-19	1	4	3	Welded pins with washers

REMARKS:

Please note that this is not an approval, but shall be considered as an assessment for use together with the above mentioned references, when applying to the authorities for classification before date of review. After this date, we should review the assessment before use. The assessment is based on experience from fire testing and the information supplied.

The nominal board thicknesses are used as input in the calculations. The design graphs and tables are developed for nominal board thicknesses. 25mm board was not tested, but characteristic conductivity derived as arithmetic mean of the average values for 20mm and 30mm boards respectively.

This assessment requires a method of application equal to the procedure described in the test reports: The boards were fixed with welded pins and washers nom. cc 350mm. The steel pins were 2,7mm thick and Cu-coated. The washers attached to the steel pins were 30mm wide and galvanized. The pins were welded to the steel through the insulation boards. All board butt joints between flanges are secured on the back face with a 200mm wide and 40mm thick piece of insulation squeezed in between the flanges. In addition a piece of insulation board was inserted between the steel web and this back board.

Any changes in the specification of the products will invalidate this assessment.

In this assessment report we have used the denotations “30-, 60- ... 210 minutes fire resistance” for fire endurance times. An assessment according to the procedure described in EN 13501-2 and ENV 13381-4 justifies the use of the terms **R30-R210**.

SINTEF NBL recommends the assessment to be returned for review after a period of 2 years, to consider any available additional data, or changes in the fire procedures.

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Summary

SINTEF NBL as (NBL/Norwegian Fire Research Laboratory) is asked to assess **PAROC FPS 17 mineral wool boards** according to the calculation procedures described in ENV 13381-4 . Both ENV 13381-4:2002 and ENV 13381-4:2007 (draft February 2007) were used in the assessment.

Basis for the analysis are available test data from SINTEF NBL carried out according to ENV 13381-4:2002.

Design Tools for prediction of proper thickness of **PAROC FPS 17 mineral wool boards** on steel sections are made **for 30 minutes to 210 minutes** endurance time in a Standard Fire Exposure for open and closed steel sections (I/H- and CHS/RHS-sections) at 30 minutes intervals. An assessment according to the procedure described in EN 13501-2 and ENV 13381-4 justifies the use of the terms **R30-R210**.

According to Annex B of ENV 13381-4:2002:

Where thicknesses of the fire protection material have been assessed from 'I' or 'H' sections with boxed protection, no change in thickness is required, i.e. the thickness for a SHS of a given A_p/V value is equal to that for the 'I' or 'H' section of the same 'box' A_p/V value.

At the request from the client only one assessment methodology was applied:

- Numerical regression analysis (ENV 13381-4 Annex H)

The steel temperature test results are averaged and corrected for stickability according to ENV 13381-4 Version February 2007 Section 3.1.12 and Annex E.

The outputs from the analysis are presented in Appendices B.

Assessment methodology

Steel temperature test data
The steel temperature test results are averaged and corrected for stickability according to ENV 13381-4 Version February 2007 Section 3.1.12 and Annex E.

3.1.12 Steel temperature
The temperature of the steel structural member determined by the mean of the web plus the mean of the flanges divided by 2 in the case of columns. For beams the steel temperature is determined by the mean of the web plus the mean of the top flange plus the mean of the lower flange divided by 3. The overall mean temperature determined above is to be used as input data for the analysis.

13.3 Correction for discrepancy in stickability and insulation performance over the thickness range tested
The data from the loaded sections will possibly need to be corrected for localized high temperatures. The data from an unloaded section shall be corrected for any discrepancies between the thickness of fire protection material applied to it and that applied to its equivalent loaded section, prior to obtaining a correction factor k(θ) which relates to stickability (see Annex E).

15 Limits of the applicability of the results of the assessment
...
The fire protection period resulting from the test and assessment is limited to the maximum period of testing or some shorter period.
For an assessment to be valid for any particular fire resistance period the loaded sections must achieve a loadbearing capacity performance as defined in EN 1363-1 of at least 90% of this period. ...
Nominal extension only beyond those variables evaluated during the test is permitted. Permitted extensions are given in Table 2.

Table 2 - Permitted Extensions

Section factor A/V	up to minimum tested to +10% of maximum tested
Fire protection material thickness	-10% to +10%

The averaged steel temperature data corrected for stickability is presented in Appendix A.

The calculations cover the tested range with respect to maximum and minimum Section Factor (+ 10%) and maximum and minimum board thickness (-10% to +10%). See Table 1.

Table 1 Tested range with respect to board thickness and Section Factor.

		Fire tests				Assessment			
Section	Fire Resistance (minutes)	Total thickness [mm]		Section Factor [m-1]		Total thickness [mm]		Section Factor [m-1]	
		min	max	min	max	min	max	min	max
Open/closed	30-210 min	20	60	54	217	20	60	50	250

Differential equation analysis
At the request from the client results from the differential equation analysis is not reported here. The analysis is however fully documented and filed at SINTEF NBL.

Numerical regression analysis
The methodology for the numerical analysis is presented in ENV 13381-4:2002 (equal to ENV 13381-4 Version February 2007).

The input data used for this methodology are the thicknesses of the fire protection system on the short column/beam sections and the temperature data corrected for stickability.

The multiple linear numerical regression analysis is conducted using the following equation:

$$t = a_o + a_1 d_p + a_2 \frac{d_p}{A_i/V} + a_3 \theta_{SC} + a_4 d_p \theta_{SC} + a_5 d_p \frac{\theta_{SC}}{A_i/V} + a_6 \frac{\theta_{SC}}{A_i/V} + a_7 \frac{1}{A_i/V}$$

The regression is performed in Excel, and the parameters a_0-a_7 are determined for steel temperature levels 350°C to 700 °C at 50 °C intervals.

For each steel temperature level (Θ_{SC}) board thicknesses (d_p) may then be calculated as a function of Section Factor (A_i/V_s) and Fire Endurance Time (t) and the regression constants using the following re-arranged equation:

$$d_p = \frac{t - a_o - a_3 \times \Theta_{sc} - a_6 \times \frac{\Theta_{sc}}{A_i/V} - a_7 \times \frac{1}{A_i/V}}{a_1 + a_2 \times \frac{1}{A_i/V} + a_4 \times \Theta_{sc} + a_5 \times \frac{\Theta_{sc}}{A_i/V}}$$

APPENDIX A shows fire test data used in the assessment.

APPENDIX B shows the output form this assessment.

Regression constants had to be multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4:2007 Section 13.5.1 Criteria for acceptability. See Appendix B.

Fire test data for use in this assessment are from the following test reports from SINTEF NBL:

- Fire test of steel beams and columns with PAROC FPS 17 fire protection boards, according to ENV 13381-4:2002 (E). (Test 1), dated 2007-03-19.
- Fire test of steel beams and columns with PAROC FPS 17 fire protection boards, according to ENV 13381-4:2002 (E). (Test 2), dated 2007-03-19.

Table A.1a: Test specimens in Test 1. Nominal section factors.

			Nominal values		
Name	**Profile**	**Column /beam**	**A_i/V_s (m^{-1})**	**Thickness insulation (mm)**	**Length (mm)**
LB-1	IPE 400	Beam	116	20	4685
RB-1	IPE 400	Beam	116	20	1000
B1-1	HEA 200	Beam	108	30	1000
B2-1	IPE 240	Beam	154	20	1000
S1-1	HEM 280	Column	50	20	1000
S2-1	HEB 300	Column	81	20	1500
S3-1	HEA 300	Column	105	20	1500
S4-1	IPE 200	Column	210	40	1500

Table A.1b: Main test results from Test 1. The loaded beam carried the applied load for 101 minutes and 50 seconds.

		Measured steel temperature at different test times [°C]					
Test specimen	Temp	0 min	30 min	60 min	90 min	120 min	122,5 min
S1-1 HEM 280 20 mm	**Max**	10	100	227	361	484	494
	Avg	10	90	211	342	465	475
S2-1 HEB 300 20 mm	**Max**	11	137	313	481	624	635
	Avg	10	128	299	466	605	610
S3-1 HEA 300 20 mm	**Max**	10	168	377	563	700	709
	Avg	9	152	357	545	682	691
S4-1 IPE 200 40 mm	**Max**	10	142	386	646	857	881
	Avg	10	125	368	619	810	831
B1-1 HEA 200 30 mm	**Max**	10	120	281	434	565	575
	Avg	10	102	255	416	553	564
B2-1 IPE 240 20 mm	**Max**	11	220	475	672	784	795
	Avg	10	201	445	652	769	780
RB-1 IPE 400 20 mm	**Max**	13	212	402	583	719	817
	Avg	10	159	353	546	697	749
LB-1 IPE 400 20 mm	**Max**	11	193	404	579	735	753
	Avg	10	152	344	521	663	674

Table A.2a: Test specimens in Test 2. Nominal section factors.

			Nominal values		
Name	**Profile**	**Column /beam**	**A_i/V_s (m^{-1})**	**Thickness insulation (mm)**	**Length (mm)**
LB-2	IPE 400	Beam	116	60	4685
RB-2	IPE 400	Beam	116	60	1000
B1-2	HEA 200	Beam	108	40	1000
B2-2	IPE 240	Beam	154	50	1000
S1-2	HEM 220	Column	63	30	1500
S2-2	HEB 450	Column	69	50	1500
S3-2	HEA 300	Column	105	60	1000
S4-2	IPE 200	Column	210	60	1000

Table A.2b*:* Main test results from Test 2. The loaded beam carried the applied load for 176,5 minutes.

		Measured steel temperature at different test times [°C]							
Test specimen	**Temp**	0 min	30 min	60 min	90 min	120 min	150 min	180 min	198 min
S1-2 HEM 220 30 mm	**Max**	18	85	195	312	429	535	627	674
	Avg	17	76	181	297	412	520	614	661
S2-2 HEB 450 50 mm	**Max**	19	46	120	221	331	437	535	583
	Avg	18	41	107	199	303	408	507	558
S3-2 HEA 300 60 mm	**Max**	19	42	123	239	365	486	602	657
	Avg	19	38	109	213	329	446	554	611
S4-2 IPE 200 60 mm	**Max**	17	75	243	461	652	798	946	1002
	Avg	17	63	211	420	612	757	904	969
B1-2 HEA 200 40 mm	**Max**	16	87	224	364	496	609	701	736
	Avg	16	76	195	334	471	591	688	727
B2-2 IPE 240 50 mm	**Max**	16	67	195	357	505	637	737	793
	Avg	16	63	175	321	469	607	721	772
RB-2 IPE 400 60 mm	**Max**	15	40	113	230	351	464	567	621
	Avg	15	38	106	207	320	430	539	597
LB-2 IPE 400 60 mm	**Max**	17	51	137	300	433	540	710	770
	Avg	16	42	108	218	333	444	559	630

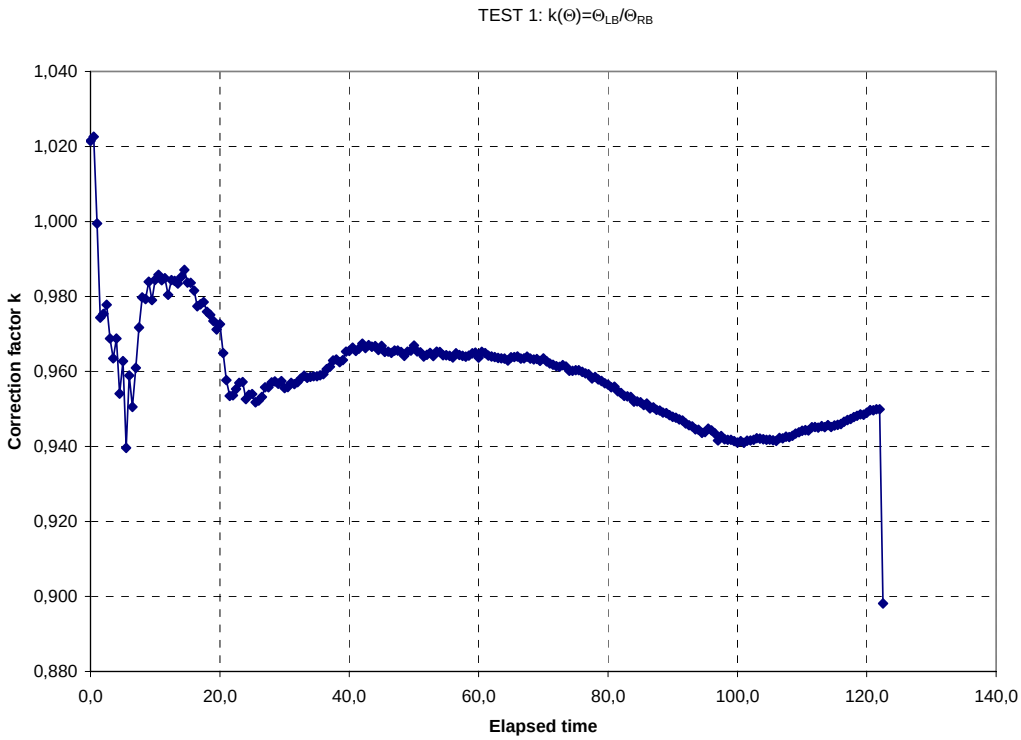


Figure 1a: Test 1: Calculated correction factors according to ENV 13381-4 Version February 2007 Section 3.1.12 and Annex E. (Values of k below 1,0 are changed to unity).

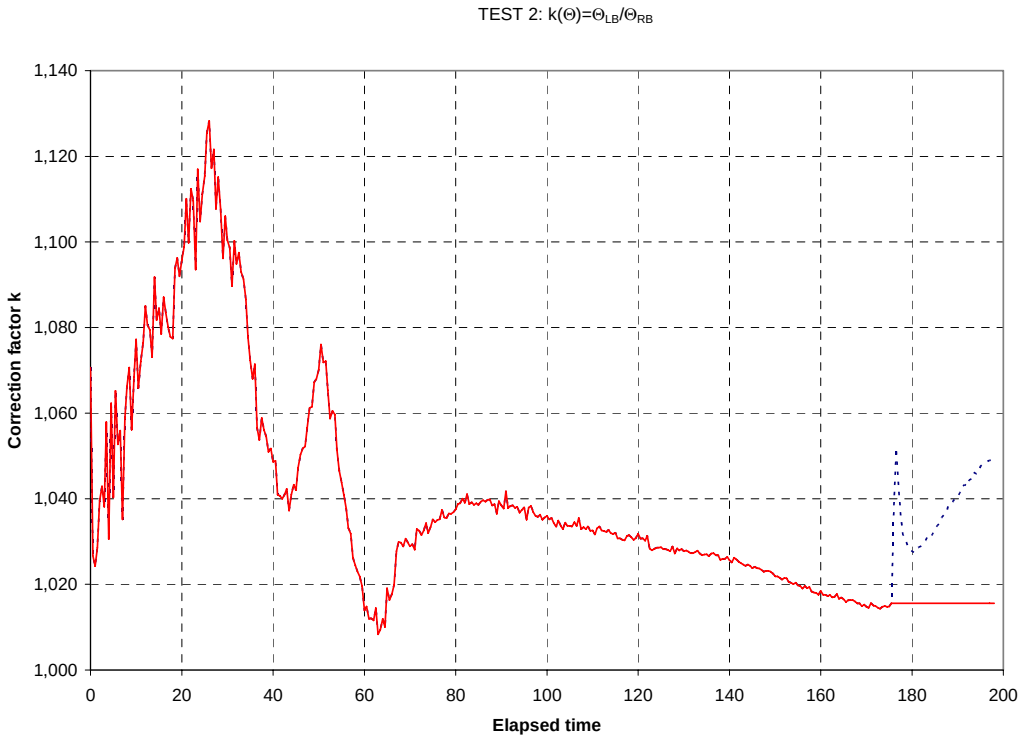


Figure 1b: Test 2: Calculated correction factors according to ENV 13381-4 Version February 2007 Section 3.1.12 and Annex E. The k-factor is defined to be constant after unloading.

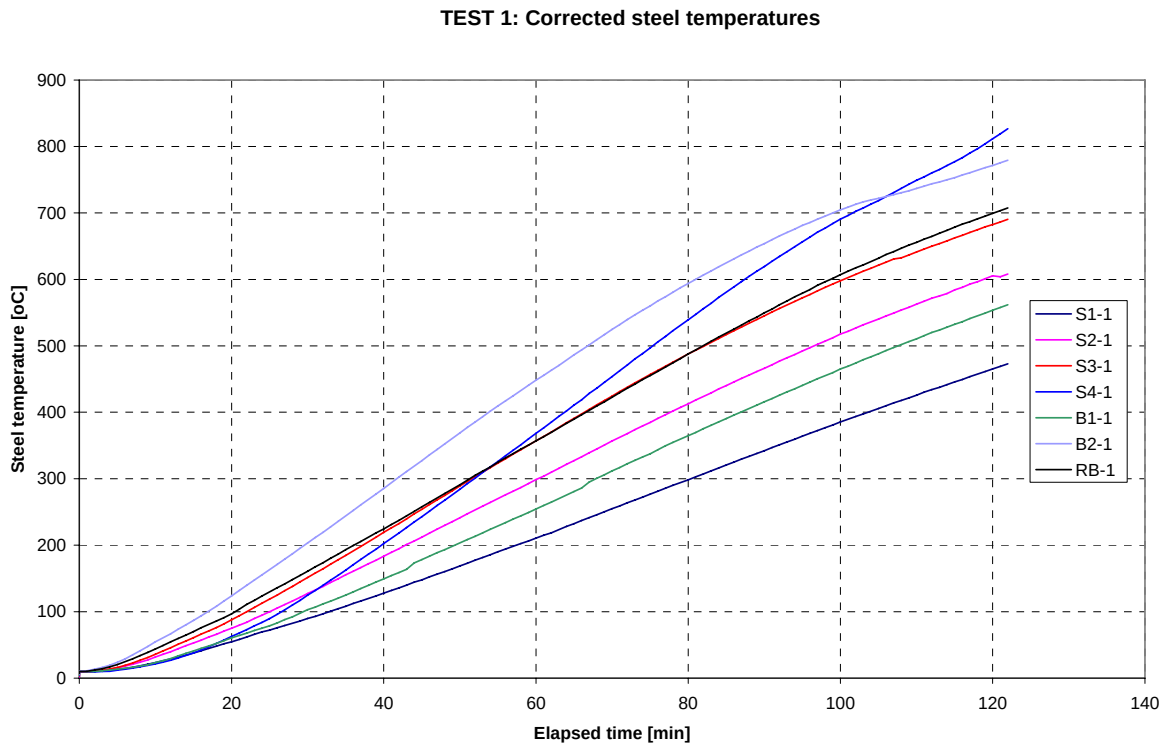


Figure 2 Test 1: Averaged and corrected steel temperatures prepared according to ENV 13381-4.

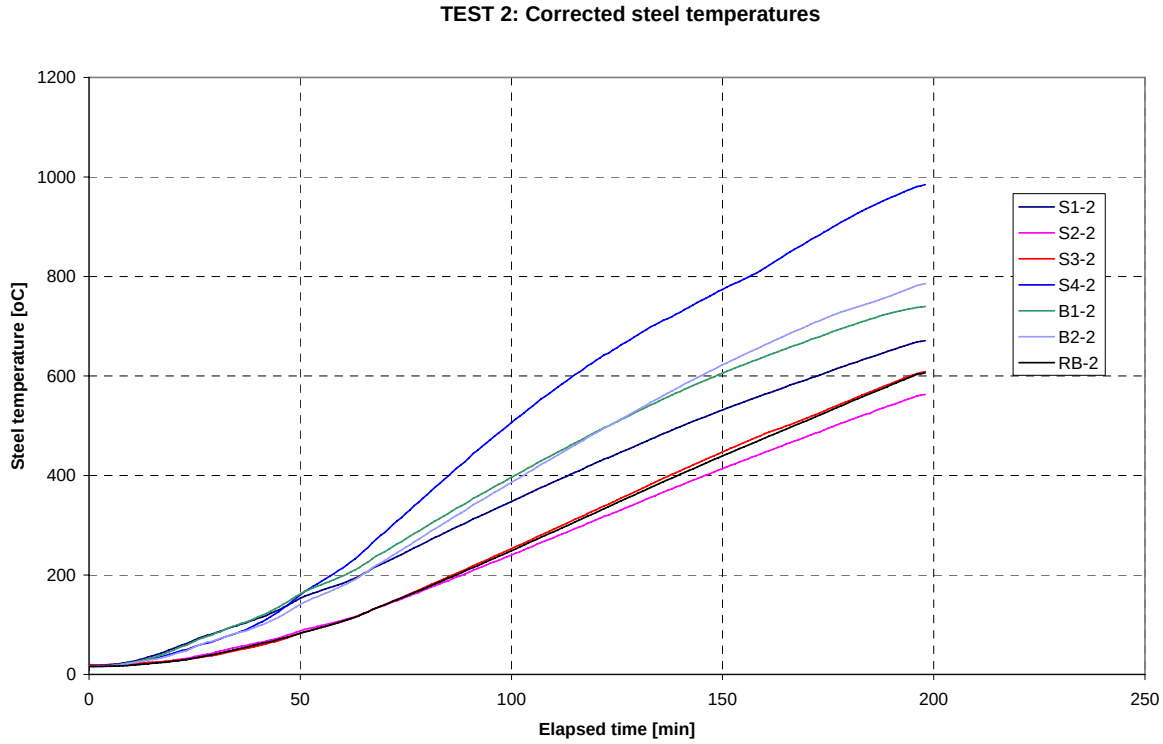


Figure 3 Test 2: Averaged and corrected steel temperatures prepared according to ENV 13381-4.

Table A.3 Test data used in numerical regression analysis. Shaded values are extrapolated values. (The value for Θ_{SC} is altered in the calculations).

Report	Item no.	Specimen nominelle data					A_i/V (calculated)	d_p [mm]	$d_p/A_i/V$	Θ_{sc}	$d_p \times \Theta_{sc}$	$d_p \times (\Theta_{sc}/(A_i/V))$	$\Theta_{sc}/(A_i/V)$	$1/(A_i/V)$	Time in minutes to corrected average steel temperature level							
		Section	Name	Config	Ai/V (m^{-1})	Thickness insulation [mm]									350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
103040.13A	1	HEM 280	S1-1	Column	50	20	**54,3**	20	0,36839026	700	14000,000	257,8731845	12,8936592	0,018419513	91,5	103,5	116,0	129,0	142,0	155,0	168,0	180,0
	2	HEB 300	S2-1	Column	81	20	**80,4**	20	0,24864428	700	14000,000	174,0509962	8,70254981	0,012432214	69,0	78,0	87,0	97,0	107,0	119,0	133,0	145,0
	3	HEA 300	S3-1	Column	105	20	**101,0**	20	0,19793388	700	14000,000	138,5537126	6,92768563	0,009896694	59,0	66,0	74,0	82,0	91,0	100,0	112,0	124,0
	4	IPE 200	S4-1	Column	210	40	**205,1**	40	0,19500733	700	28000,000	136,5051298	3,41262825	0,004875183	58,0	64,0	69,5	75,0	81,0	87,0	94,0	102,0
	5	HEA 200	B1-1	Beam	108	30	**114,9**	30	0,26120223	700	21000,000	182,8415627	6,09471876	0,008706741	77,0	87,0	97,0	108,0	119,0	132,0	139,0	157,0
	6	IPE 240	B2-1	Beam	154	20	**156,0**	20	0,12823294	700	14000,000	89,76305896	4,48815295	0,006411647	48,0	54,0	60,0	67,0	73,0	81,0	89,0	99,0
	7	IPE 400	RB-1	Beam	116	20	**117,3**	20	0,17053383	700	14000,000	119,3736806	5,96868403	0,008526691	59,0	67,0	74,0	82,0	90,0	99,0	109,0	120,0
103040.13A	8	HEM 220	S1-2	Column	63	30	**63,8**	30	0,47001511	700	21000,000	329,010575	10,9670192	0,01566717	100,0	113,0	127,0	140,0	156,0	172,0	189,0	221,0
	9	HEB 450	S2-2	Column	69	50	**69,2**	50	0,72255552	700	35000,000	505,7888647	10,1157773	0,01445111	132,0	146,0	161,0	177,0	193,0	225,0	261,0	296,0
	10	HEA 300	S3-2	Column	105	60	**105,7**	60	0,56783893	700	42000,000	397,487251	6,62478752	0,009463982	125,0	138,0	151,0	165,0	180,0	194,0	218,0	243,0
	11	IPE 200	S4-2	Column	210	60	**216,5**	60	0,27710799	700	42000,000	193,9755902	3,2329265	0,004618466	79,0	85,0	92,0	99,0	106,0	115,0	124,0	133,0
	12	HEA 200	B1-2	Beam	108	40	**114,4**	40	0,34958673	700	28000,000	244,7107131	6,11776783	0,008739668	90,0	101,0	112,0	123,0	135,0	148,0	164,0	180,0
	13	IPE 240	B2-2	Beam	154	50	**156,9**	50	0,3186696	700	35000,000	223,0687212	4,46137442	0,006373392	93,0	103,0	113,0	123,0	134,0	145,0	157,0	170,0
	14	IPE 400	RB-2	Beam	116	60	**118,8**	60	0,50503544	700	42000,000	353,5248066	5,89208011	0,008417257	126,0	139,0	153,0	167,0	181,0	195,0	221,0	248,0

Table B.1 **Critical Steel Temperature 350°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,998273	a_o = 0
Critical steel temperature:			**350** °C		R^2	0,99655	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	40	50	60	
60	20	20	25	40	50		
70	20	20	30	50	60		
80	20	20	40	50			
90	20	20	40	60			
100	20	20	40	60			
110	20	25	50				
120	20	25	50				
130	20	30	50				
140	20	30	50				
150	20	30	60				
160	20	40	60				
170	20	40	60				
180	20	40	60				
190	20	40					
200	20	40					
210	20	40					
220	20	40					
230	20	40					
240	20	40					
250	20	40					

Table B.2 **Critical Steel Temperature 400°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,998041	a_o = 0
Critical steel temperature:			**400** °C		R^2	0,996085	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	25	40	50	60
60	20	20	20	40	50	60	
70	20	20	25	40	50		
80	20	20	30	50	60		
90	20	20	30	50			
100	20	20	40	60			
110	20	20	40	60			
120	20	20	40	60			
130	20	25	40				
140	20	25	50				
150	20	25	50				
160	20	25	50				
170	20	30	50				
180	20	30	60				
190	20	30	60				
200	20	30	60				
210	20	40	60				
220	20	40	60				
230	20	40	60				
240	20	40					
250	20	40					

Table B.3 **Critical Steel Temperature 450°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,997913	a_0 = 0
Critical steel temperature:			**450**	°C	R^2	0,99583	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	25	40	40	50
60	20	20	20	30	40	50	60
70	20	20	20	40	50	60	
80	20	20	25	40	50		
90	20	20	25	40	60		
100	20	20	30	50			
110	20	20	40	50			
120	20	20	40	60			
130	20	20	40	60			
140	20	20	40	60			
150	20	20	50				
160	20	25	50				
170	20	25	50				
180	20	25	50				
190	20	25	50				
200	20	25	50				
210	20	30	60				
220	20	30	60				
230	20	30	60				
240	20	30	60				
250	20	30	60				

Table B.4 **Critical Steel Temperature 500°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,997794	a_o = 0
Critical steel temperature:			**500** °C		R^2	0,995592	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	20	30	40	50
60	20	20	20	25	40	50	60
70	20	20	20	30	40	50	
80	20	20	20	30	50	60	
90	20	20	25	40	50		
100	20	20	25	40	60		
110	20	20	30	50	60		
120	20	20	30	50			
130	20	20	30	50			
140	20	20	40	60			
150	20	20	40	60			
160	20	20	40	60			
170	20	20	40	60			
180	20	20	40				
190	20	20	50				
200	20	20	50				
210	20	25	50				
220	20	25	50				
230	20	25	50				
240	20	25	50				
250	20	25	50				

Table B.5 **Critical Steel Temperature 550°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,997696	a_o = 0
Critical steel temperature:			**550**	°C	R^2	0,995398	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	20	25	30	40
60	20	20	20	20	30	40	50
70	20	20	20	25	40	50	60
80	20	20	20	30	40	50	
90	20	20	20	30	50	60	
100	20	20	20	40	50		
110	20	20	25	40	60		
120	20	20	25	40	60		
130	20	20	30	50	60		
140	20	20	30	50			
150	20	20	30	50			
160	20	20	40	50			
170	20	20	40	60			
180	20	20	40	60			
190	20	20	40	60			
200	20	20	40	60			
210	20	20	40				
220	20	20	50				
230	20	20	50				
240	20	20	50				
250	20	20	50				

Table B.6 **Critical Steel Temperature 600°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,998351	a_o = 0
Critical steel temperature:			**600** °C		R^2	0,996705	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	20	20	25	40
60	20	20	20	20	25	40	40
70	20	20	20	20	30	40	50
80	20	20	20	25	40	50	60
90	20	20	20	25	40	50	60
100	20	20	20	30	40	60	
110	20	20	20	40	50	60	
120	20	20	20	40	50		
130	20	20	25	40	60		
140	20	20	25	40	60		
150	20	20	25	50	60		
160	20	20	30	50			
170	20	20	30	50			
180	20	20	30	50			
190	20	20	40	60			
200	20	20	40	60			
210	20	20	40	60			
220	20	20	40	60			
230	20	20	40				
240	20	20	40				
250	20	20	40				

Table B.7 **Critical Steel Temperature 650°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,998572	a_o = 0
Critical steel temperature:			**650** °C		R^2	0,997146	k_{MOD}=0,97
	Fire Resistance time in minutes						
F/A	30	60	90	120	150	180	210
50	20	20	20	20	20	25	30
60	20	20	20	20	20	30	40
70	20	20	20	20	25	40	40
80	20	20	20	20	30	40	50
90	20	20	20	25	30	40	50
100	20	20	20	25	40	50	60
110	20	20	20	30	40	50	
120	20	20	20	30	50	60	
130	20	20	20	40	50	60	
140	20	20	20	40	50		
150	20	20	20	40	60		
160	20	20	25	40	60		
170	20	20	25	50	60		
180	20	20	25	50			
190	20	20	30	50			
200	20	20	30	50			
210	20	20	30	60			
220	20	20	30	60			
230	20	20	40	60			
240	20	20	40	60			
250	20	20	40	60			

Table B.8 **Critical Steel Temperature700°C:** Design table for **PAROC FPS 17 mineral wool boards** for fire protection on steel to Standard Fire Exposure. Design values from ENV 13381-4 numerical regression. Regression constants multiplied with factor k_{MOD} = 0,97 to satisfy ENV 13381-4 Section 13.5.1 Criteria for acceptability.

Open and closed steel sections					Multiple R	0,998565	a_o = 0
Critical steel temperature:			**700** °C		R^2	0,997132	k_{MOD}=0,97
F/A	Fire Resistance time in minutes						
	30	60	90	120	150	180	210
50	20	20	20	20	20	20	25
60	20	20	20	20	20	25	30
70	20	20	20	20	20	30	40
80	20	20	20	20	25	30	40
90	20	20	20	20	30	40	50
100	20	20	20	20	30	40	50
110	20	20	20	25	40	50	60
120	20	20	20	25	40	50	60
130	20	20	20	25	40	50	
140	20	20	20	30	50	60	
150	20	20	20	30	50	60	
160	20	20	20	40	50		
170	20	20	20	40	60		
180	20	20	20	40	60		
190	20	20	20	40	60		
200	20	20	20	50			
210	20	20	25	50			
220	20	20	25	50			
230	20	20	25	50			
240	20	20	25	60			
250	20	20	30	60			

ENV 13381-4:2007 Section 13.5.1 Criteria for acceptability:

Steps 1-5 in Annex H are performed:

The constants a_0-a_7 are used to calculate times to design temperatures using the following equation:

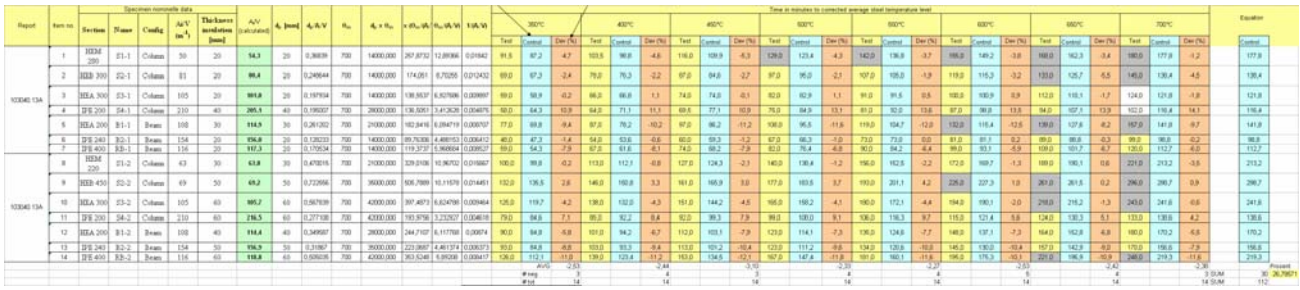
$$t = a_o + a_1 d_p + a_2 \frac{d_p}{A_i/V}$$
$$+ a_3 \theta_{SC} + a_4 d_p \theta_{SC} + a_5 d_p \frac{\theta_{SC}}{A_i/V} + a_6 \frac{\theta_{SC}}{A_i/V} + a_7 \frac{1}{A_i/V}$$

The criteria are as follows:

The acceptability of the analysis within the range of steel section temperature (as defined by 10.7 or the sponsor) and duration of the test shall be judged up to the maximum temperature tested on the following basis:

a) For each short section the predicted time to reach the design temperature shall not exceed the time for the corrected temperature to reach the design temperature by more than 15%.
b) The mean value of all percentage differences as calculated in a) shall be less than zero.
c) A maximum of 30% of individual values of all percentage differences as calculated in a) shall be more than zero.

Modification of the analysis should be made until the criteria of acceptability are met.



For a modification factor k_{MOD} 0,97 all the three criteria are met:

a) Maximum deviation in predicted time 14,1%
b) Mean value less than zero
c) 26,8 %